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Soft tissue management and augmentation in implant surgery*

Weichgewebemanagement und -augmentation in der Implantatchirurgie

G. Iglhaut

Introduction: While innovations in augmentation surgery mainly focused on hard tissue grafting in the past, attention has more and more been directed to the soft tissue as a limiting factor. A variety of techniques is available for augmenting deficient alveolar crestal bone. But reliable and lasting wound closure, an essential factor deciding the success of surgery, is a problem in major grafting cases. The design and tension-free mobilization of flaps for wound coverage as well as the meticulous adaptation of the wound margins and the optimal preservation of the nutritive supply are of prime importance for a predictable outcome of treatment. In this contribution various techniques are described and their applications are discussed.
Material and method: Extended incisions and large flaps may cause considerable iatrogenic injuries and disrupt the anatomy of the gingiva and mucosa. Free or pedicled soft tissue grafts are useful minimally invasive options for wound coverage which help to avoid these drawbacks. Their benefits lie in preserving the anatomy and ensuring coverage for hard tissue healing. The associated vertical and horizontal soft tissue augmentation avoids unfavorable vestibular flattening.
Discussion and conclusion: Abutment connection also provides options for generating a circular keratinized mucosa of sufficient thickness around the emergence profile of the implant neck, abutment and suprastructure. Both the thickness of the peri-implant soft tissue and its keratinization can be enhanced with appropriate techniques. Still, a point should be made to build a sufficiently thick and keratinized peri-implant mucosa prior to abutment connection by soft tissue grafting. Once endosseous implants are uncovered, corrective measures are limited and present a major challenge for the surgeon's skills.
The author describes a minimally invasive tunneling technique adopted from plastic periodontal surgery for covering exposed implant surfaces.

Keywords: Soft tissue management, flap management, free soft tissue grafts, pedicled soft tissue grafts, abutment connection, recession, surgical coverage of implants

Einführung: Nachdem Innovationen in der Augmentationschirurgie primär den Fokus des Hartgewebeaufbaus hatten, erkannte man mehr und mehr das Weichgewebe als limitierenden Faktor. Defizitäre Alveolarkammareale mit Knochenaufbauten zu rekonstruieren, kann mit verschiedenen Methoden realisiert werden. Jedoch stellt sich bei umfangreichen Augmentaten der sichere und langfristige Wundverschluss, ein entscheidender Faktor für den Erfolg der operativen Maßnahme, als Problem dar. Das Design und die spannungsfreie Mobilisation von bedeckenden Wundlappen sowie die präzise mikrochirurgische Wundrandadaption unter bestmöglichem Erhalt der Blutversorgung sind von großer Bedeutung für einen vorhersehbaren Therapieerfolg.
Material und Methode: Umfangreiche Inzisionen und Lappenbildungen können jedoch zu teils erheblichen chirurgischen Traumata führen und die Anatomie von Gingiva und Mukosa zerstören. Zur Vermeidung dieser Nachteile bieten sich freie oder gestielte Weichgewebetransplantate als minimal invasive Alternative zur Defektdeckung an. Der Vorteil liegt im Erhalt anatomischer Strukturen und gleichzeitiger gedeckter Hartgewebeheilung.
Diskussion und Schlussfolgerung: Mit Freilegungsoperationen bestehen weitere Optionen, ausreichend dicke, zirkulär keratinisierte Schleimhaut am Durchtrittsprofil des Implantathalses, des Aufbauteils und der Suprakonstruktion zu generieren. Trotzdem muss es das Ziel sein, bereits vor der Freilegung mit Weichgewebetransplantaten eine ausreichende Dicke und Keratinisierung periimplantär aufzubauen. Nach erfolgter Freilegung eines enossalen Implantates sind korrektive Maßnahmen nur noch bedingt möglich und stellen höchste Ansprüche an die chirurgischen Fähigkeiten des Behandlers. Als Therapieansatz zur Deckung von exponierten Implantatoberflächen wird vom Verfasser eine minimal invasive Tunneltechnik aus der plastischen Parodontalchirurgie beschrieben.
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Schlüsselwörter: Weichgewebemanagement, Wundlappenbildung, freie Transplantate, gestielte Transplantate, Freilegungstechniken, Rezessionsdeckung, Implantate

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1 Introduction

In the early 1960's endosseous implant osseointegration marked a major step towards the functional rehabilitation of patients with severely atrophic mandibles [12]. In the late 1980's guided bone regeneration (GBR) substantially contributed to the wide-spread use of implants [21]. This dramatically expanded the range of indications so that implant surgery became an important subspecialty of dentistry. New concepts were developed to satisfy esthetic expectations in the esthetically critical regions [26]. Implants were no longer placed in the residual local host bone; their position was rather prosthodontically driven. Inadequate alveolar ridges at the prospective implant site were grafted with hard tissue. Increasing esthetic expectations were not only a challenge for dental technology (white esthetics). The focus shifted more and more to the peri-implant soft tissue (pink esthetics). The presence of a near-perfect mucogingival line became a sine qua non for an esthetically flawless outcome.

Aside from guided bone regeneration, a variety of techniques was developed and used for soft tissue augmentation [17]. Soft tissue surgery increasingly turned out to be a limiting factor for successful long-life coverage of what often were bulky bone grafts. Wound dehiscence with subsequent infection was a major complication [24]. It may lead to partial or total graft loss [58]. Rising expectations of flap surgery explain why peri-implant soft tissue management assumed focal importance. This specifically applies to minimally invasive techniques [67, 78]. These were thought to ensure high outcome predictability and to improve patient comfort. As a result, they were widely used in soft tissue surgery. In fact, atraumatic approaches are nowadays employed successfully in endodontic, implant-driven and regenerative periodontal surgery [19, 23, 41].

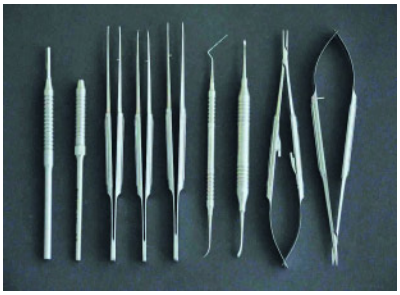

Figure 1 KLS Martin microsurgery kit.
Abbildung 1 Mikrochirurgie-Set, Fa. KLS Martin.

Figure 2 Acrylic perfusion cast showing the vascular pattern of the vestibular maxilla and mandible in primates.
Abbildung 2 Darstellung der Blutgefäßversorgung mit Kunststoffperfusion im vestibulären Ober- und Unterkiefer des Primaten [23].

2 Basic principles of surgical soft tissue management

Today high expectations are attached to implant treatment particularly in esthetically sensitive regions. Given successful osseointegration, the prime criterion of success is a natural appearance of the implant-supported restoration. Ceramic materials for crowns and abutments perfectly mimic dental hard tissue. But what also counts for an esthetically satisfactory outcome is the maintenance or restoration of peri-implant and gingival soft tissues. Therefore, the overriding objectives of soft tissue surgery must be a harmonious gingival margin, the presence of properly shaped interdental papillae and a tissue color and texture matching that of the surrounding tissue. Abundant peri-implant volume should be built to simulate alveolar yokes and ensure long-term stability of the peri-implant mucosa. Although the presence of a sufficiently wide attached gingiva around teeth and implants is controversial [73–75, 77], there is general agreement that a stable tissue barrier is essential for long-term survival [15]. The absence of scar tissue is another important factor for avoiding late impairment and guaranteeing high-quality mucosal structures.

Flap incisions

Soft tissue flap healing is affected by various factors. As a matter of principle, surgery should be atraumatic. This begins with the choice of appropriate microsurgical instruments (Fig. 1) en-

Figure 3 Extensive augmentation with the shell technique at site 13–14.
Abbildung 3 Umfangreiche Augmentation mit Schalentechnik in regio 13–14.

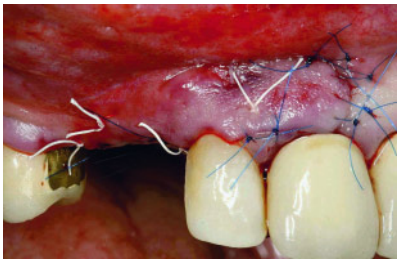

Figure 4 Microsurgical vestibular suture at site 11–14.
Abbildung 4 Mikrochirurgischer Nahtverschluss vestibulär in regio 11–14.

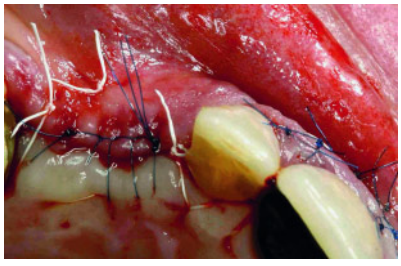

Figure 5 Microsurgical palatale suture at site 11–14.
Abbildung 5 Mikrochirurgischer Nahtverschluss palatinal in regio 11–14.

Lappentechnik	Indikation	Vorteile	Nachteile
Mucoperiosteal flap	• Submerged or non-submerged implants • Minor grafts	• Low technique sensitivity • Adequate nutrient supply of flap	• Poor flap mobilization • Compromised nutrient supply of bone • Deperiosting promotes bone resorption • Poor mono-layer nutrient supply of soft tissue grafts
Mucosal flap (Split flap)	• Submerged or non-submerged implants • Soft tissue graft • Implant uncoverage • Osteoplastic bone grafting	• Excellent flap mobilization • Nutrient supply of bone preserved • Bone resorption prevented • Double-layer nutrient supply of soft tissue grafts	• High technique sensitivity • Risk of flap perforation • Exposure of high-risk structures (e.g. mental nerve) problematic
Combined mucoperiosteal /mucosal flap	• Implants with hard and soft tissue grafting	• Easy flap mobilization • Reliable primary wound healing • Nutrient supply of bone partially preserved • Bone resorption largely prevented	• High technique sensitivity • Risk of flap perforation • Exposure of high-risk structures (e.g. mental nerve) problematic
Double split flap	• Extensive implant placement with hard and soft tissue grafting	• Excellent vertical flap mobilization • Multi-layer coverage of graft • Reliable primary wound healing • Nutrient supply of bone partially preserved • Bone resorption largely prevented	• Very high technique sensitivity • Risk of flap perforation • Major surgical trauma • Compromised nutrient supply of flap • Exposure of high-risk structures (e.g. mental nerve) problematic

Table 1 Classification of relevant flap techniques.
Tabelle 1 Übersicht bedeutender Lappentechniken.

abling the surgeon to work with utmost precision. But no matter what the technique, soft tissue will have to be cut and thus injured. To gain a sufficient overview a flap of adequate size should be raised so that structures at risk can be seen and spared, the blood supply can be preserved and the flap can be extended without tension to ensure complete coverage of the field [42].

An intact nutritive supply is thought to be a prime factor for wound healing [7, 9]. Therefore, incisions should be meticulously planned with due attention to the anatomy of the arteries supplying the gingiva and mucosa. Preferably, this should already be done during implant planning. Incisions should always be parallel to the vessels or lie at the borderline separating two vascular territories. Six vascular territories have been defined in the oral cavity [54, 76]: The maxilla is mainly supplied by the posterior and anterior alveolar and palatal arteries, the mandible by the inferior alveolar, the buccal, the sublingual and the mental arteries. As the main feeders anastomose extensively, incisions need not be feared to interrupt the blood flow.

Branches of the main arteries enter the gingiva from 3 sides: the dental artery through the periodontal ligament, the interseptal artery through the alveolar bone and a supraperiosteal branch from the oral mucosa. The dental artery transports blood to the pulp and the periodontal ligament. It forms a dental vascular basket which ends in a dense gingival vascular plexus. This consists of a circular sulcular plexus with gingival loops at the junction with the sulcular epithelium and is only supplied by the dental and interseptal arteries [46]. The area supplied by it is clearly distinct from that fed by the vestibular supraperiosteal branches and is ideal for marginal gingival incisions in terms of an oblique intrasulcular cut towards the alveolar limbus. Vertical incisions should be avoided, if possible, because the supraperiosteal gingival branch (Fig. 2) takes an oblique course from disto-apical to mesio-gingival [48]. For a better overview the intrasulcular incision can be extended horizontally. When it reaches the papilla, it should be continued along the papilla base vertical to the bone (Fig. 3). Unlike intrasulcular cuts through the papilla, this helps to avoid a loss of vertical papilla height [71], because the papilla is supplied by the interseptal artery. As the main gingival vessels course from posterior to anterior, vertical releasing incisions, if unavoidable, should be made anteriorly (Fig. 3). Trapezoid flap incisions are, consequently, a poor choice and should be omitted [42]. In edentulous ridges a mid-crestal avascular zone of about 1–2 mm without anastomoses separates the buccal from the lingual/palatal vasculature [20]. Called linea alba, it is the ideal site for horizontal incisions. This explains why the optimal flap design is based on a mid-crestal incision in edentulous arches with an intrasulcular extension along 1 to 2 neighboring teeth (Fig. 4, 5).

Suture technique	Suture pattern	Suture strength	Needles
Fixation sutures	Deep crossed mattresss sutures	5–0 (1.5 metric) PTFE polytetrafluorethylen (e.g. Cytoplast)	DS 13 DS 16
	Interrupted suture	5–0 (1.5 metric) ePTFE expand. polytetrafluorethylen (e.g. Gore-tex)	DS 13 DS 17
	Vertical looped mattress suture		
Apposition sutures	Interrupted suture	6–0 (1.0 metric) PVLF polyvinylidendifluorid (e.g. Seralene)	DS 12 DS 15
		7–0 (0.7 metric) PVLF polyvinylidendifluorid (e.g. Seralene)	DS 9 DS 12
	Continuous loopd mattress suture	6–0 (1.0 metric) polypropylen (e.g. Premilene, Serapren)	DS 12 DS 15
		7–0 (0.7 metric) polypropylen (e.g. Premilene, Serapren)	DS 9 DS 12
	Vertical mattress suture		

Table 2 Overview of suture techniques.
Tabelle 2 Übersicht Nahttechniken.

Flap dissection and handling (Table 1)

In implant surgery bone grafts for repairing alveolar bone loss often have to be covered by coronal advancement. The classical coronal advancement flap [57] was designed as a **mucoperiosteal flap** with subsequent periosteal slitting, a simple, time-saving and reliable technique. As the blood flow through the flap is largely preserved, the wound heals well. But flap mobility limits the extent of coronal advancement. In addition, the inevitable lingual/palatal shift of the mucogingival line is undesirable esthetically and, because of vestibular flattening, also functionally.

In plastic periodontal surgery sharp supraperiosteal dissection with a scalpel (blade 15C) proved to be useful for atraumatic flap dissection. If the mucosa is very delicate, microblades (Beavertail No. 69) are a helpful alternative [5]. This dissection technique (**mucosal flap**, split flap) ensures that flaps can be raised atraumatically and accurately without tearing or crushing even if the soft tissue is thin and fragile. Supraperiosteal dissection does not expose the alveolar bone and thus prevents ridge resorption [56]. Another major benefit is that the flap is easily expanded. This guarantees tension-free reliable wound closure. Interposed soft tissue grafts heal predictably thanks to the bilaminar nutritive supply [6]. The high technique sensitivity is, however, a drawback.

Mucosal flaps are indicated whenever the nutritive function of the periosteum overlying the bone needs to be preserved. Osteoplastic grafting techniques like bone spreading or bone splitting, abutment connection and soft tissue grafting are examples. For onlay grafts (GBR, block grafts, etc.) **mucoperiosteal flaps** (centrally) **combined** with **mucosal flaps** (apically and laterally) are useful options. With this technique most of the horizontal and vertical ridge augmentations can be reliably covered without tension (Figs. 3, 4, 5). **Double split flaps** for plastic coverage are very rarely needed [33]. They are reserved for patients with a sufficiently thick mucosa and require high surgical skills.

Flap bedding and retraction are critical for uneventful healing. The mobilized soft tissue flaps should be secured to the buccal and lingual mucosa with stay sutures and passively kept out of the field with retractors (e.g. Branemark retractors). This provides an excellent overview even of extensive fields and prevents flap bruising and crushing. Drying of the wound by excessive suction should be avoided. Frequent wetting with gauze swabs soaked in physiologic saline is helpful.

Wound closure

Meticulous adaptation of the wound margins is essential for uneventful wound healing. The perfectly trimmed cut edges should be sutured flush without tension. Traction and mobility should be avoided [55]. If the cut edges cannot be adapted without tension, another mucosal split flap should be raised to rule out the main cause of wound dehiscence and subsequent infection [58, 63]. Split flap extension at this point in time is usually associated with major tissue bleeding and complicates wound closure. A point should, therefore, be made to raise a sufficiently large flap from the outset. Together with tension-free flap adaptation meticulous suturing (Table 2) is critical for the early revascularization of the mucosa [13]. For both, microsurgical techniques supported by magnifying lenses and monofilament sutures strength 5–0, 6–0 or 7–0 are helpful [14]. 6–0 and 7–0 suture-needle combinations effectively prevent injuries at the site, because the thin threads tear at a certain force. Non-resorbable sutures of PVDF (polyvinylidene difluoride, e.g. Seralene) are particularly useful thanks to their tissue compatibility. As these sutures are designed for adapting the wound margins, they are called **adaptation sutures** (Figs. 4, 5). Thanks to their smooth surface and tear resistance PTFE (polytetrafluorourethane) sutures strength 5–0 like Cytoplast have worked well for flap positioning and fixation. Unlike ePTFE sutures, which tend to accumulate plaque, PTFE sutures have properties similar to those of smooth monofilament threads. They are used for deep crossed horizontal mattress sutures, i.e. **fixation sutures**, approximate the wound margins and reliably keep them together so that healing is not perturbed by traction or mobility (Figs. 4, 5). All this explains why two different suture materials are needed for augmentations.

Revascularization can be enhanced by autogenous platelet-rich plasma (PRP). A split-mouth study showed PRP to be a potent stimulator of capillary regeneration (> 30 %) and to significantly accelerate wound healing in the first 10 days [47]. All of these measures are de-

Graft	Indications	Advantages	Disadvantages
Free mucosal graft	• No attached mucosa • Mobile frenula and muscles • Periimplant mucosa at risk of recession	• Reliable wound healing • Minor swelling • Little postop. pain	• Poor color match • Major palatal defect • Rarely postop. pain • Rarely paresthesia
Free connective tissue graft	• Mucosal thickening • Minor grafting procedures • Coverage of recession-related exposure of titanium surfaces • Socket closure	• Very good color match • High reliability • Minor swelling • Little postop. pain	• Risk of postop. bleeding • Rarely postop. pain • Rarely paresthesia
Combined connective tissue/onlay graft	• Mucosal thickening • Plastic coverage/closure post immediate implant placement • Plastic coverage/closure post ridge preservation • Papilla repair	• Preservation of anatomical structures • Very good color match • High reliability • Minor swelling • Little postop. pain	• Risk of postop. bleeding • Rarely postop. pain • Rarely paresthesia
Inlay/onlay graft	• Crestal soft tissue repair • Crestal soft tissue preservation post ridge preservation • Plastic coverage/closure post ridge preservation • Papilla repair	• Very good color match • High reliability • Minor swelling • Little postop. pain	• Risk of postop. bleeding • Rarely postop. pain • Rarely paresthesia
Pedicled palatal connective tissue graft	• Mucosal thickening • Two-layer closure post major bone grafting • Plastic coverage/closure post immediate implant placement • Plastic coverage/closure post ridge preservation • Papilla repair	• Preservation of anatomical structures • Very good color match • High reliability • Major soft tissue grafting	• Very high technique sensitivity • Long healing time • Rarely postop. pain • Rarely paresthesia

Table 3 Overview of soft tissue grafting techniques.
Tabelle 3 Übersicht Weichgewebetransplantate.

(Tab. 1–3 und Abb. 1–30: G. Iglhaut)

signed to guarantee reliable closed wound healing and to help prevent swelling and pain. Depending on the extent of the procedure sutures should be drawn within 7 to 14 days (Figs. 6, 7).

3 Free grafts

Coronal advancement flaps are routinely used in implant surgery for covering grafts. For these, extensive incisions and large flap sizes are needed. These cause substantial surgical trauma and disrupt the soft tissue with resultant flattening of the vestibulum and a lingual/palatal shift of the mucogingival line. These drawbacks can be avoided by using free or pedicled soft tissue grafts (Table 3). They leave the anatomy intact, guarantee closed hard tissue healing, minimize the risk of infection and expand the soft tissue volume. Buccal transposition of the tissue gained during abutment connection helps to compensate for tissue loss. However, free grafts disrupt the nutritive supply so that wound healing is impaired. For this reason it is important to take a closer look at free graft healing.

Free mucosal grafts

Originally free mucosal grafts were used in mucogingival surgery for expanding the keratinized gingiva and removing undesirable frenula (Fig. 8). The need to augment the keratinized gingiva has, however, been questioned, because the usefulness of a sizable keratinized gingiva is controversial. Clinical and experimental animal studies by *Wennstrom* and *Lindhe* [74] suggested that a keratinized gingiva around natural teeth was not necessarily needed for maintaining periodontal health. This was confirmed for peri-implant health in other studies by *Wennstrom, Bengazi* and *Lekholm* [75]. Recent studies showed significantly more clinical and immunological signs of infection and radiographic signs of bone loss around implants with a thin layer of keratinized mucosa (< 2 mm) [11, 79]. On account of its poor mechanical stability a thin mucosa (< 2 mm) tends to recede more severely and to be more susceptible to infection despite adequate plaque control during the maintenance phase [2, 59]. This explains why recurrent infection is an absolute indication for soft tissue repair.

Techniques for free mucosal grafts were first described in the mid-1960's [31, 52]. The first step consists in developing the graft site by sharp dissection of the mucosa from the periosteum. The mucosal flap thus raised is retracted towards apical and secured with resorbable sutures. The defect to be covered is measured with a periodontal probe for graft sizing. The hard palate distal to the lateral incisors and mesial to the first molars is the preferred donor site (Fig. 12). Clinical studies [66] showed that mucosa of sufficient volume for harvesting mucosal grafts is also present near the tuberosity. After outlining the graft size with a blade the graft is dissected free with a 15C blade parallel to the surface at a depth of 1.5 to 2 mm. It is immediately adapted to the recipient site and sutured to the coronal wound margin (Fig. 9). If deemed necessary, the apical wound margin is secured to the peri-

Figure 6 Healing of vestibular wound at site 11–14 after 2 weeks.
Abbildung 6 Wundheilung nach 2 Wochen vestibulär in regio 11–14.

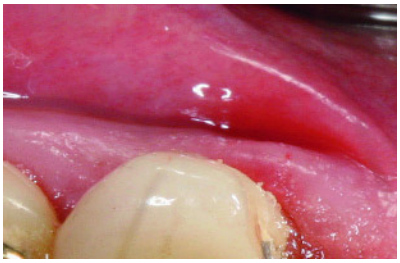

Figure 7 Healing of palatal wound at site 11–14 after 2 weeks.
Abbildung 7 Wundheilung nach 2 Wochen palatinal in regio 11–14.

Figure 8 Non-attached peri-implant mucosa at site 44–45.
Abbildung 8 Bewegliche periimplantäre Mukosa in regio 44–45.

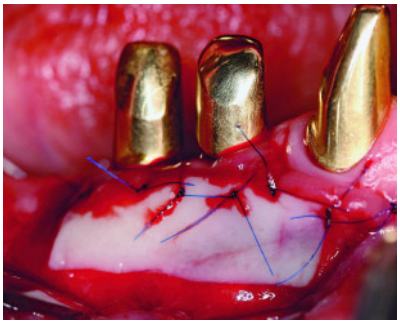

Figure 9 View post fixation of a free mucosal graft.
Abbildung 9 Zustand nach Fixation eines freien Schleihauttransplantates.

osteum with resorbable sutures to rule out graft mobility. To conclude with, the graft is pressed against its support with wetted gauze for 5 to 10 minutes. The palatal donor site should be covered with a protective plate dressing for 10 to 14 days postoperatively. The sutures are drawn after a week.

Subepithelial connective tissue grafts

Connective tissue grafts are mainly used during implant treatment in the esthetically critical region. Clinical and radiographic studies showed bony recession of 1.5 to 2 mm to occur around implant necks [3, 18]. It is attributable to physiologic bone remodeling associated with implant uncoverage or occurs during osseointegration of non-submerged implants, depends on the three-dimensional implant position [32, 70]. This leads consecutively to periimplant soft tissue recession [16, 29] and may cause substantial esthetic compromise [10]. A thin gingival phenotype appears to carry a higher risk of recession during implant treatment [38]. For this reason augmenting the peri-implant mucosa with connective tissue grafts was proposed for patients with the thin morphotype A [51]. Called biotype conversion [39], this procedure is apparently capable of transforming a delicate gingiva to the more resistant morphotype B and of compensating minor recession around the implant neck. This adds stability to the peri-implant soft tissue. For this reason grafts should routinely be placed in the upper anterior region.

The technique of graft harvesting was first described by *Langer* et al. [45]. The original "trap door" incision has meanwhile been replaced by an atraumatic single-incision modification [34, 49]. An incision of about 1.5 mm in depth is made parallel to the teeth 3 mm away from the palatal gingival margin distal to the lateral incisor and mesial to the first molar. Then a 1 mm thick cover flap is dissected free parallel to the palatal surface. Another supraperiosteal incision 1 mm apical to the first one serves as a support for repositioning the cover flap and harvesting the bridge flap. The graft is released through vertical incisions at both soft tissue ends and a horizontal incision in the apical part of the tunnel, transferred to the recipient site and secured with sutures (Fig. 11). To conclude with, the flap is pressed against the support for 5 to 10 minutes. The author omitted to close the palatal wound with sutures. In his experience tension-free repositioning of the thin cover flap with an overlying plate dressing worked better (Fig. 12). Suturing exposes the thinned out flap to traction and may cause wound necrosis. Like after other palatal graft harvesting procedures, patients are instructed to wear a protective plate dressing for 10 to 14 days.

The large amount of fatty tissue in grafts harvested from the premolar region is thought to be a drawback because of the potentially substantial resorption and volume loss (Fig. 13). This can be avoided by harvesting the grafts palatally at the site of the second and third molars and the tuberosity. The fibrous texture of these grafts facilitates their adaptation and suture fixation (Fig. 14). Their opaque-whitish color is an added benefit, because it camouflages dark titanium and root surfaces. The small graft size obtainable and the difficult access are limiting factors.

Inlay (sandwich) grafts

Inlay grafts were developed for augmenting the soft tissue of edentulous ridges prior to prosthodontic treatment [25, 44, 61]. They are wedge-shaped and thicker than connective tissue grafts with a strip of epithelium attached to them. Inlay grafts are also harvested from the palate in the premolar region. The region distal to the second or third molars is an alternative donor site. Grafts harvested in the molar region are fibrous in texture. Their resorption rate is clearly lower than that of premolar grafts (20 to 40 %).

For harvesting a palatal horizontal crestal incision is made. This is followed by supraperiosteal dissection towards apical to form a subepithelial pouch. The inlay grafts are placed in the pouch and secured with a horizontal mattress suture on the connective tissue side (Fig. 15). They are not completely covered

Figure 10 View 2 weeks postoperatively.
Abbildung 10 Zustand nach 2 Wochen post Op.

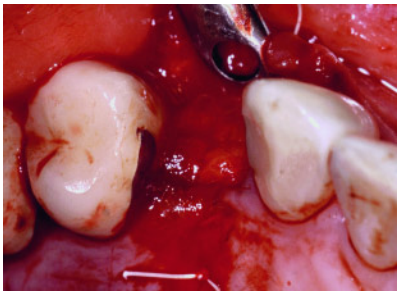

Figure 11 Free soft tissue graft at site 14.
Abbildung 11 Freies Bindegewebetransplantat fixiert in regio 14.

Figure 12 View post connective tissue harvest at site 23–35 2 weeks postoperatively.
Abbildung 12 Zustand 2 Wochen post Op nach Bindegewebeentnahme in regio 23–35.

Figure 13 Free soft tissue graft harvested in the premolar region.
Abbildung 13 Freies Bindegewebetransplantat aus Prämolarenregion.

and the strip of epithelium should come to lie orally. Their bilaminar nutrition from the mucosal flap covering the wound and the periosteum promotes wound healing and ensures graft survival. Inlay grafts help to maintain the soft tissue contours of deficient extraction sockets and provide the requisite soft tissue prior to hard tissue grafting.

Onlay grafts

Onlay grafts are soft tissue grafts which were developed for vertical soft tissue augmentation of edentulous ridges [25, 50, 60]. They are free grafts harvested from the palate with a nutritive supply from the donor site and the wound margins. How much soft tissue can be gained vertically depends on the initial graft volume, on wound healing and the surviving graft portion.

In implant surgery onlay grafts are used for covering wounds after extractions and simultaneous augmentation, i.e. ridge preservation, and help to prevent a shift of the mucogingival line [43]. Like inlay grafts, they need large amounts of donor tissue and are best harvested in the premolar region at the sites of the second and third premolars by sharp supraperiosteal dissection in a shape matching that of the socket to be grafted. Tightly sutured to the de-epithelialized gingival margin of the socket, they are initially supplied by diffusion. This requires an intimate contact with the wound. Success rates were reported to be limited [43]. Partial and total necrosis has been described (up to 40 %). Thanks to a simplified harvesting technique using a punch, grafts of sufficient size for successfully covering extraction sockets are now available [37]. Reported graft losses are few.

Combination onlay-connective tissue grafts

The small contact area of onlay grafts appears to explain the high graft loss rates reported. Subepithelial connective tissue grafts have a much larger contact area so that their survival rates are much higher. To improve revascularization a combination onlay-interpositional connective tissue graft was developed for preprosthetic soft tissue augmentation of edentulous ridge segments [62]. A modified version of this graft has been used in the esthetically critical region for covering extraction sockets, for augmentation and post immediate implant placement with packing of the gap between the buccal wall and the implant (jumping distance), if needed [36, 65]. This minimally invasive technique, which does not need any superficial incisions, is highly successful and minimizes patient discomfort. *Iglhaut* and *Stimmelmayr* reviewed their patients seen between 2002 and 2006 to shed light on primary healing after 49 immediate implant placements and 46 minimally invasive ridge preservations. Graft necrosis with graft loss and open secondary healing was only found in 2 cases. The success rate was 97.9 %. The benefits of the technique are multiple: The connective tissue component improves the revascularization of the onlay component and accelerates healing. The soft tissue is augmented vertically and horizontally without unfavorable vestibular flattening. The wound at the donor site is largely covered by a cover flap so that patient comfort is enhanced.

Post extractions a supraperiosteal buccal tunnel is made with a 15C blade. The tuberosity and the premolar region are the preferred donor sites. First the onlay component matching the size of the socket is excised by sharp supraperiosteal dissection with a blade. Then a connective tissue tongue pedicled to the onlay component is dissected free (Fig. 16) and the donor site is dressed with collagen sponges. For alveolar soft tissue closure the connective tissue component is pulled through the buccal tunnel and secured with horizontal mattress sutures. The onlay component is adapted flush with the de-epithelialized gingival margin (Figs. 17, 18). The sutures can be drawn after 7 to 14 days, when closed healing of the alveolar wound is completed, (Figs. 19, 20).

Pedicled palatal soft tissue flaps

This technique was described for soft tissue coverage and augmentation of maxillary defects [40]. As the flap is har-

Figure 14 Free soft tissue graft harvested at the site of the second and third molars.
Abbildung 14 Freies Bindegewebetransplantat aus 2. und 3. Molarenregion.

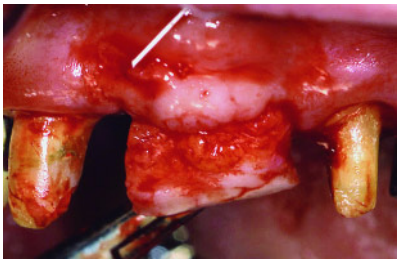

Figure 15 Placement of an inlay graft in the anterior maxilla.
Abbildung 15 Insertion eines Einlagerungstransplantates (Inlaygraft) in OK-Frontzahnbereich.

Figure 16 Combination onlay-connective tissue graft.
Abbildung 16 Kombiniertes Onlay-Bindegewebetransplantat.

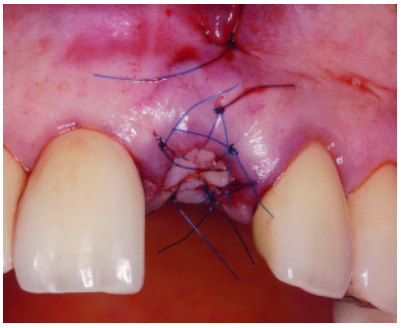

Figure 17 Socket closure after immediate implant placement at site 21.
Abbildung 17 Alveolenverschluss nach Sofortimplantation in regio 21.

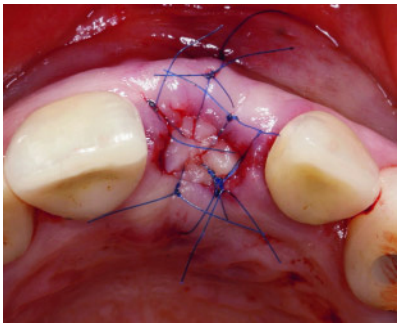

Figure 18 Socket closure after immediate implant placement at site 21.
Abbildung 18 Alveolenverschluss nach Sofortimplantation in regio 21.

Figure 19 Vestibular wound healing 2 weeks postoperatively.
Abbildung 19 Vestibuläre Wundheilung 2 Wochen post Op.

vested palatally, the keratinized gingiva and the vestibulum are left untouched. The vascular pedicle ensures an adequate blood flow and uneventful healing. Thanks to their high success rate (< 98 %) and their wide range of indications pedicled palatal soft tissue flaps have multiple uses. These include socket closure after immediate implant placement and ridge preservation, soft tissue augmentation, papilla repair, repair of defects and dehiscences, multi-layer wound closure after extensive grafting procedures (block grafts, vertical augmentation, etc.) and the management of peri-implantitis in esthetically critical regions. However, they are highly technique sensitive and associated with more morbidity. In the anterior region deep palatal rugae may make flap dissection difficult. The palatal soft tissue should have a thickness of more than 3 mm. The use of surgical plates is recommended to prevent injuries and post-procedural bleeding.

The technique for raising pedicled palatal soft tissue flaps is similar to that for soft tissue grafts. An incision is made about 3 mm away from the gingival margin. Depending on the size of the site of interest this incision is carried from the incisive papilla to the premolar region with due attention to keeping the neurovascular bundle intact. Then a cover flap with a thickness of 1 to 2 mm is dissected parallel to the surface. The outlines of the connective tissue flap are sharply dissected with a blade and the flap is raised subperiosteally with a periosteal elevator. The graft is then rotated into the site to be covered (Fig. 24) and secured deep to the vestibular flap with deep horizontal mattress sutures. The vestibular and palatal wounds are closed with interrupted or continuous sutures.

Pedicled palatal rotation flaps

Originally developed for closing oro-antral communications, this flap is designed for socket closure in patients with a thin palatal mucosa (less than 3 mm). A cover flap need not be dissected. As the flap is raised by supraperiosteal dissection, the large palatal wound is only covered by periosteum. As a result, a surgical plate is indispensable for protecting the palatal donor site and preventing post-procedural bleeding. Because of the poor color match the flap should not be extended into the vestibulum.

4 Implant uncoverage techniques

Surgery for uncovering implants is an important aspect of peri-implant soft tissue management. It is intended to provide a thick, circular keratinized mucosa at the emergence profile of the implant neck, the abutment and the suprastructure. Various techniques are available for improving the thickness and attachment of peri-implant soft tissues. The prime objective should be to generate an adequately thick and keratinized mucosa with soft tissue grafts before uncovering implants. Hard tissue deficits detected during abutment connection

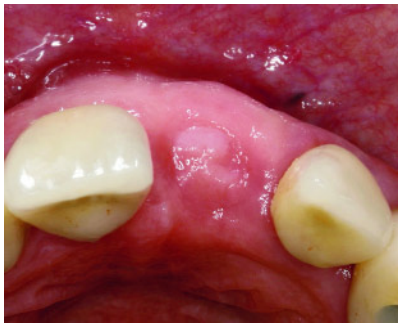

Figure 20 Palatal wound healing 2 weeks postoperatively.
Abbildung 20 Palatinale Wundheilung 2 Wochen post Op.

Figure 21 Vestibular view post implant uncoverage with roll flap technique.
Abbildung 21 Vestibulärer Zustand nach Freilegung mit Rolllappen.

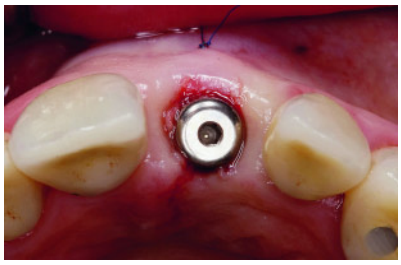

Figure 22 Palatal view post implant uncoverage with roll flap technique.
Abbildung 22 Palatinaler Zustand nach Freilegung mit Rolllappen.

Figure 23 View post insertion of implant-retained crown at site 21.
Abbildung 23 Zustand nach Eingliederung der Implantatkrone in regio 21.

require grafting with primary wound closure. Once endosseous implants have been uncovered, the scope of corrective surgery is limited and puts the surgeon's skills to a hard test.

Excisional technique

Uncovering implants by resection is only indicated, if the neighboring alveolar ridge is covered by an adequately thick attached mucosa. Blades, punches, electrosurgical instruments or lasers are the instruments of choice [8]. The tissue overlying the healing abutment is removed with a minimally invasive technique. It goes without saying that for these techniques a keratinized gingiva of adequate vestibular width is needed. Indications for tissue punching are limited.

Soft tissue conditioning technique

This technique is designed for shaping and conditioning the redundant mucosa overlying the alveolar crest by partially pushing back the keratinized gingiva. Tissue-sparing semilunar excisions are made with a blade or a semicircular tissue punch in the palatal third of the implant position and gently pushed away with a slender cylindrical gingiva former. This is left in place for 1 to 2 weeks and then replaced by a gingiva former with a larger diameter for progressively shaping and conditioning the tissue to the point of obtaining a harmonious soft tissue line.

The minimal surgical trauma reduces peri-implant bone loss and preserves or conditions the papilla [27]. This technique is indicated in patients with anterior single-tooth implants.

Advancement flap technique

To avoid excisions advancement flaps are the simplest option for uncovering implants [72]. Their principle consists in dividing the keratinized mucosa overlying the crest (Fig. 25) and in transferring stable soft tissue from palatal or lingual to the vestibular side (Fig. 26). This guarantees that the implant neck is surrounded by keratinized mucosa and the vestibular peri-implant volume is augmented horizontally and vertically.

A crestal incision is made at the level of the palatal implant shoulder and extended into the vestibulum by trapezoid releasing cuts, if necessary. The flap above the implant and its vestibular extension, if any, is designed as a mucosal flap. As the periosteum overlying the alveolar bone is left untouched, the flap can be advanced vestibularly and apically and secured with a periosteal suture. This technique helps to improve and optimize the peri-implant soft tissue by secondary wound healing even in cases with no more than a slender band of attached mucosa.

Healing abutments facilitate the fixation and vertical positioning of the flap. Simple as it is, this technique predictably adds width to the keratinized gingiva both in the upper and the lower jaw and optimizes pre-existent tissue structures. For this reason, advancement flaps have become the most important standard technique in implant surgery.

Roll flap technique

The roll flap technique was originally developed for preprosthetic soft tissue augmentation of crestal defects [1]. It is particularly well suited for uncovering single-tooth implants in the esthetic zone. Its advantage is that it transposes the soft tissue overlying the implant cover screw and preserves it. The buccal mucosa, which is susceptible to recession, is thickened and tissue loss is compensated. In addition, the thin gingival morphotypes A1 and A2 are turned into the more stable morphotype B and, as an esthetic benefit, an alveolar yoke can be simulated (Fig. 23).

A tongue-shaped buccally pedicled incision is made above the implant cover screw and carried towards palatal across the crest. The papillae are spared. Using a new blade the area incised is de-epithelialized before raising a connective tissue flap. Then a supraperiosteal buccal incision is made to shape a tunnel for accommodating the flap. The tip of the flap is secured with a horizontal mattress suture from the deep end of the tunnel and the roll flap is pulled into the pre-fashioned tunnel (Figs. 21, 22).

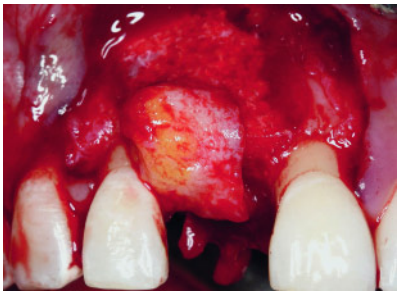

Figure 24 View post soft tissue augmentation with palatally pedicled soft tissue flap at site 11.
Abbildung 24 Zustand nach Weichgewebeaugmentation mit palatinal gestielten Bindegewebelappen in regio 11.

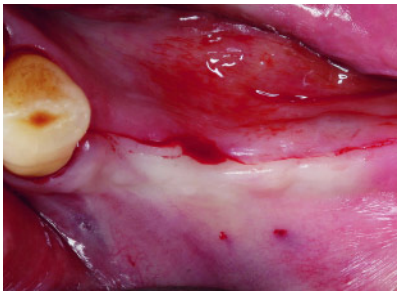

Figure 25 Mid-crestal incision for implant uncoverage with the advancement flap technique.
Abbildung 25 Midkrestale Inzision bei Freilegung mit Verschiebelappentechnik in regio 44–46.

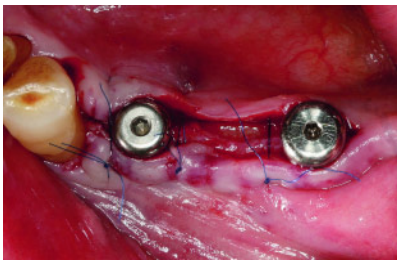

Figure 26 View post implant uncoverage with the advancement flap technique at site 44–46.
Abbildung 26 Zustand nach Freilegung mit Verschiebelappentechnik in regio 44–46.

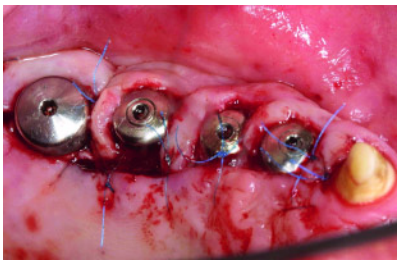

Figure 27 View post uncoverage of multiple implants with the Palacci technique.
Abbildung 27 Zustand nach Freilegung multipler Implantate mit Palacci-Technik.

Papilla flap technique (Palacci technique)

This technique is designed for uncovering multiple implants in the esthetic zone [53]. It is reserved for patients with abundant keratinized tissue overlying the crest at the implant sites horizontally. Given enough mucosa, the papilla soft tissue can be regenerated with pedicled miniflaps. The high technique sensitivity is, however, a drawback.

After perimucosal probing of the implant position an incision is made along the palatal implant shoulders and a split-thickness flap is raised and retracted vestibularly. Then the cover screws are removed and healing abutments are placed, before the flap is uprighted. At the first implant position a mesially pedicled miniflap of 1 to 2 mm in width is cut parallel to the palatal wound margin and rotated approximally. This is followed by elevating miniflaps for one implant position after the other. These minipflaps are also rotated approximally and secured with interrupted sutures (Fig. 27). The papilla height thus achievable is, however, limited to 3 mm.

Inlay graft technique (Grunder technique)

The inlay graft technique was also developed for uncovering multiple implants in the esthetic zone [28]. It is indicated in patients with poorly keratinized ridges for vertical and horizontal soft tissue augmentation and papilla repair. Free mucosal grafts carry a high risk of partial or total papilla necrosis. Also, the availability of palatal mucosal grafts may be a limiting factor.

The mucosal flap is dissected like advancement flaps along the palatal implant border and healing abutments are placed before the flap is transposed vestibularly and vertically. The resulting approximal defects are packed with appropriately shaped free mucosal grafts (inlay/onlay grafts) harvested from the palate or tuberosity and firmly adapted to the site of interest with crossed horizontal mattress sutures. This is important for graft survival, because graft nutrition exclusively depends on plasma diffusion in the first few postoperative days. It should be noted that, like with the Palacci technique, the papilla height achievable is limited to 3 mm.

5 Repair of soft tissue defects

Techniques for repairing soft tissue defects have so far only been addressed in single-case studies. Consequently, their predictability is poorly understood. This explains why techniques derived from plastic periodontal surgery have to be used for the surgical management of soft tissue defects. A well proven approach developed by the author is described below.

Repair of peri-implant mucosal recession

Recession of the peri-implant mucosa is caused by various factors (Fig. 28). Poor three-dimensional implant positioning is thought to be a prime cause [22, 70]. A poor peri-implant bone volume at the implant shoulder [64], a thin soft tissue phenotype [39], a wide implant diameter [30] and peri-implant infections [4] have also been incriminated. The coverage of implant surfaces exposed by recession has so far only been addressed in a single study albeit with inconclusive results [14]. Coronal advancement flaps [5] were used in 10 patients for repairing recessions. While the soft tissue was significantly improved clinically in all of them, shrinkage of the regenerated mucosa by 34 %, on average, was noted within no more than 6 months. Complete coverage of the defects was not achieved in any one case.

In the past decade minimally invasive tunneling techniques were developed and used clinically for repairing recessions around natural teeth with good success [68, 69]. Supported by microsurgical instruments, these help to repair mucosal loss without superficial incisions. The associated minimal surgical trauma of the marginal gingiva guarantees early and reliable wound healing. This is particularly important for the peri-implant mucosa. A modified tun-

Figure 28 Recession of the peri-implant mucosa at sites 12 and 22.
Abbildung 28 Rezessionen periimplantärer Mukosa in regio 12 und 22.

Figure 29 View immediately post repair of peri-implant recession at sites 12 and 22 with the modified tunneling technique.
Abbildung 29 Zustand unmittelbar nach periimplantärer Rezessionsdeckung in regio 12 und 22 mit modifizierter Tunneltechnik.

Figure 30 View 12 months post repair of peri-implant recession at sites 12 and 22 with the modified tunneling technique.
Abbildung 30 Zustand nach periimplantärer Rezessionsdeckung in regio 12 und 22 mit modifizierter Tunneltechnik 12 Monate post Op.

neling technique derived from plastic periodontal surgery was first presented by the author for covering exposed implant surfaces in 1998 [35]. This technique is described below.

The mucosa is incised in the mesial interdental space. The incision begins at the mucogingival line and is extended vertically for about 4 to 5 mm in an apical direction towards the reflection. Unlike at the margin of the peri-implant mucosa, this incision provides access for tension-free soft tissue graft placement without the risk of mucosal tearing. Through this access the tissue around the implant and the two neighboring teeth is undermined with tunneling instruments for flap dissection. A mucosal flap is elevated from the vestibular tissue to the size needed for covering the recession tension-free by coronal advancement. Then a free soft tissue graft is harvested from the palate. This graft should have a stable volume and be opaque so that the mucosa is stabilized and the dark color of the implant is camouflaged. Fibrous grafts from the tuberosity or from the area palatal to the second and third molars are the best candidates. Through the vestibular access these can easily be carried to the margin of the peri-implant mucosa without the risk of tearing and firmly secured with circumferential sutures (Fig. 29). With this technique recessions of up to 2 mm in height can be repaired (Fig. 30). DZZ

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